# Electron Density SZA Dependence: Comparing PFISR Data Against Models

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# Outline

- Review of ion production and loss rates.
- Chapman function to determine neutral density line integral.
- Scale height depends on neutral parameters.
- IRI and E-CHAIM prediction of electron density change with solar zenith angle (SZA).
- Experiment results.
- Summary and conclusions.

# Electron Density Model Calculation

- Electron density continuity equation governed by production and loss rates:

$$\frac{\partial n_{i,e}}{\partial t} + \nabla \cdot (n_{i,e}\mathbf{v}_{i,e}) = q_{i,e} - l_{i,e}$$

- Examples of electron losses depend of electron temperature:

**Table 5.** Recombination Loss Rates

| Reaction | Rate, $cm^3\ s^{-1}$ |
|---|---|
| $H^+ + e \rightarrow H$ | $4.43 \times 10^{-12}/T_e^{0.7}$ |
| $He^+ + e \rightarrow He$ | $4.43 \times 10^{-12}/T_e^{0.7}$ |
| $N^+ + e \rightarrow N$ | $4.43 \times 10^{-12}/T_e^{0.7}$ |
| $O^+ + e \rightarrow O$ | $4.43 \times 10^{-12}/T_e^{0.7}$ |
| $N_2^+ + e \rightarrow N_2$ | $1.80 \times 10^{-7}/T_e^{0.39}$ |
| $NO^+ + e \rightarrow NO$ | $4.20 \times 10^{-7}/T_e^{0.85}$ |
| $O_2^+ + e \rightarrow O_2$ | $1.60 \times 10^{-7}/T_e^{0.55}$ |

From Huba et al. (2000)

# Electron Density Model Calculation

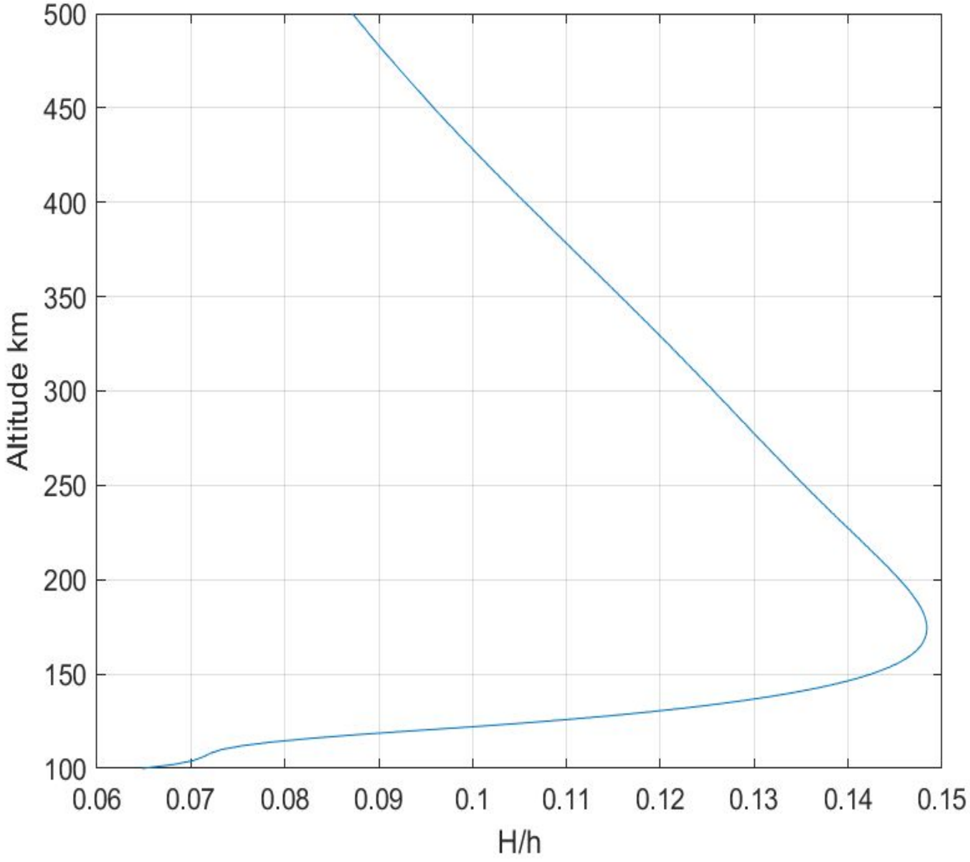
- Production depends on
  - Neutral density
  - Sun's intensity at a particular wavelength
  - Ionization cross section per wavelength for a particular neutral species
- And is attenuated by
  - Absorption cross section per wavelength and neutral species
  - Line integral over the neutral density from Sun to target
    - Approximated using Chapman functions

$$q_l(z) = n_l(z) \sum_{\lambda} \sigma_l^{(i)}(\lambda) \phi_{\infty}(\lambda) \times \exp\left[ - \sum_m \sigma_m^{(a)}(\lambda) \int_z^{\infty} n_m(s)\, ds \right]$$

$$I_p = n_p H \, \mathrm{ch}(\mathrm{X}_\mathrm{p}, \chi_\mathrm{p})$$

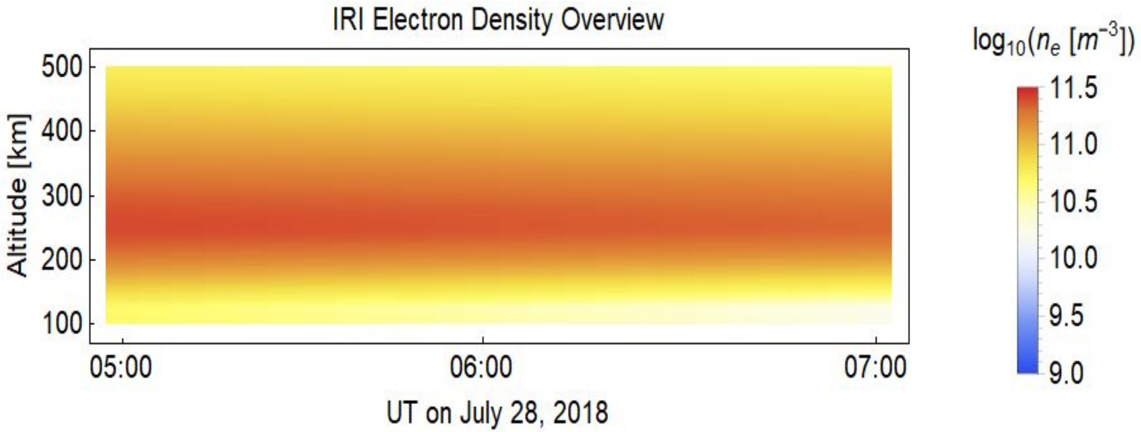
From Huba et al. (2000)

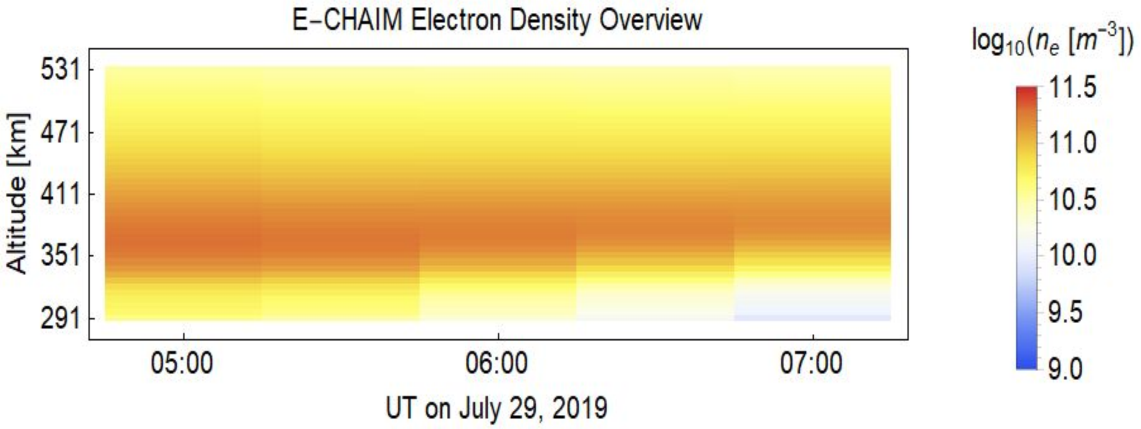
- Chapman functions often assume constant H
- H=R*T_n / (M_a*g)
- R=8.31 J/(mol.K)
- M_a is the average mol mass using density profile
- T_n is the neutral Temperature K
- MSIS-E-90 Atmosphere Model provides scaled height vs. altitude
- H is not constant



# Model Predictions of Electron Density

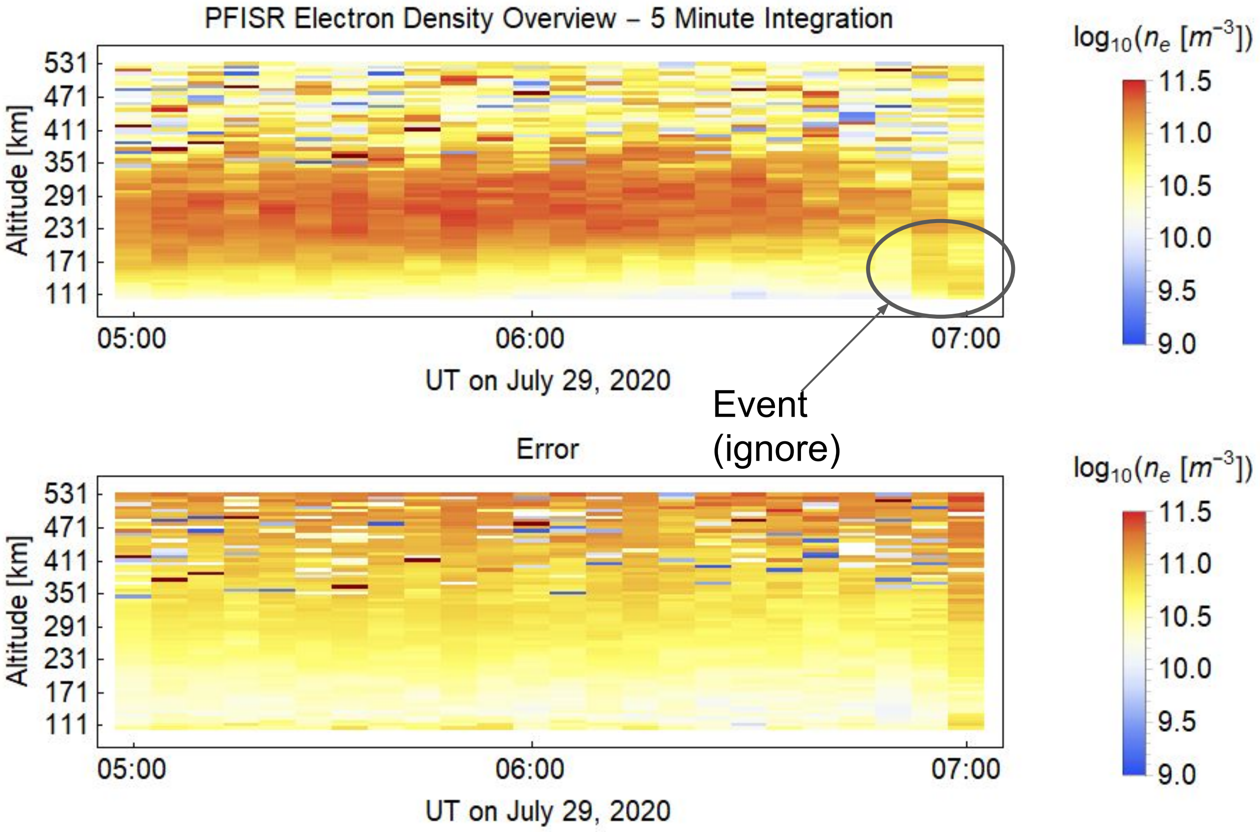
- Gradual electron density drop at lower altitudes with time as SZA increases
- Solar spot number is a significant parameter for IRI



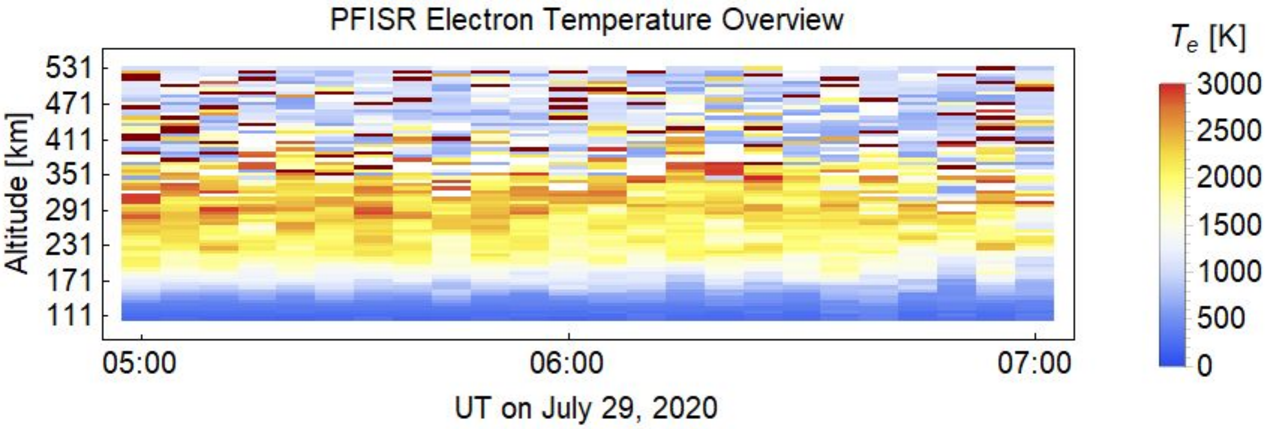
# PFISR Electron Density Data

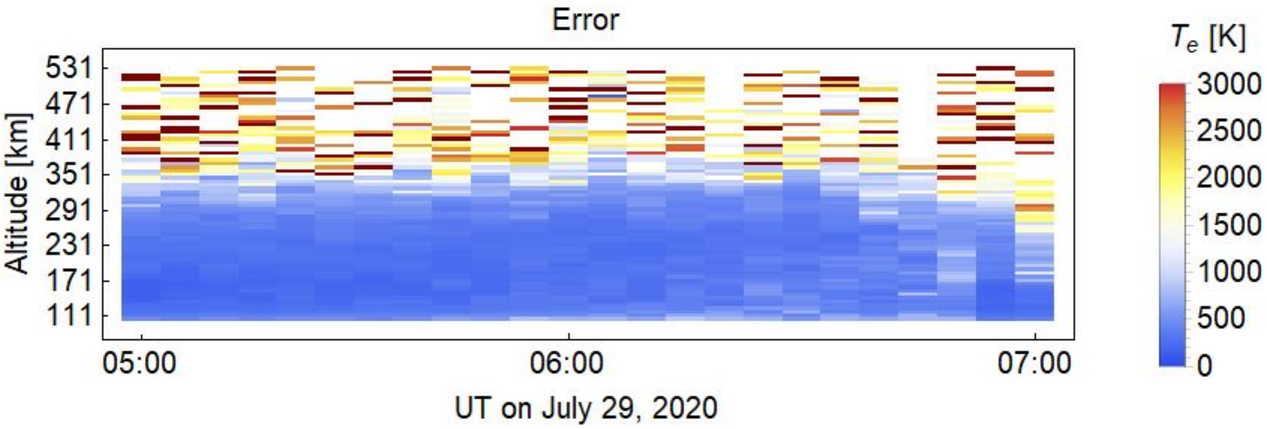
- At first this trend is visible in the PFISR data
- low altitude density enhancement at around 7:00 UT



# PFISR Electron Temperature Data

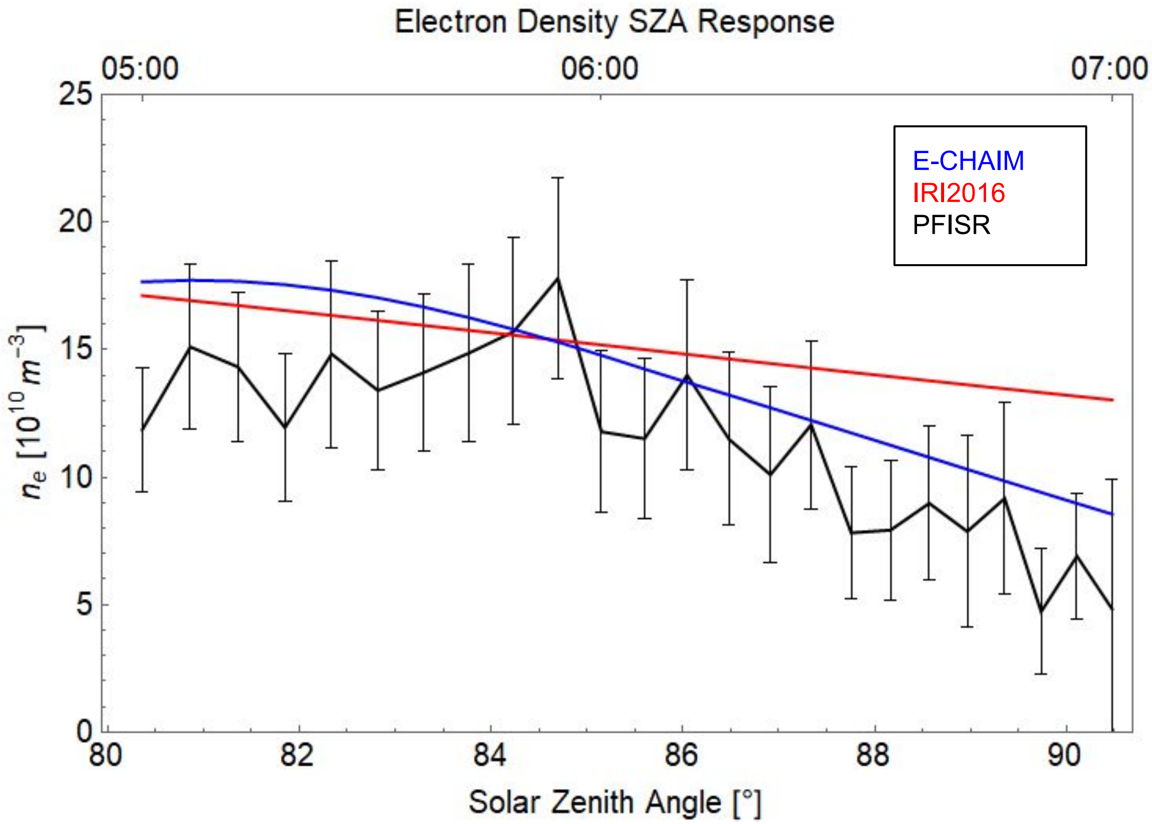
- Electron cooling near 7:00 UT drops which affects loss rates
- Note the error increase at 7:00 UT



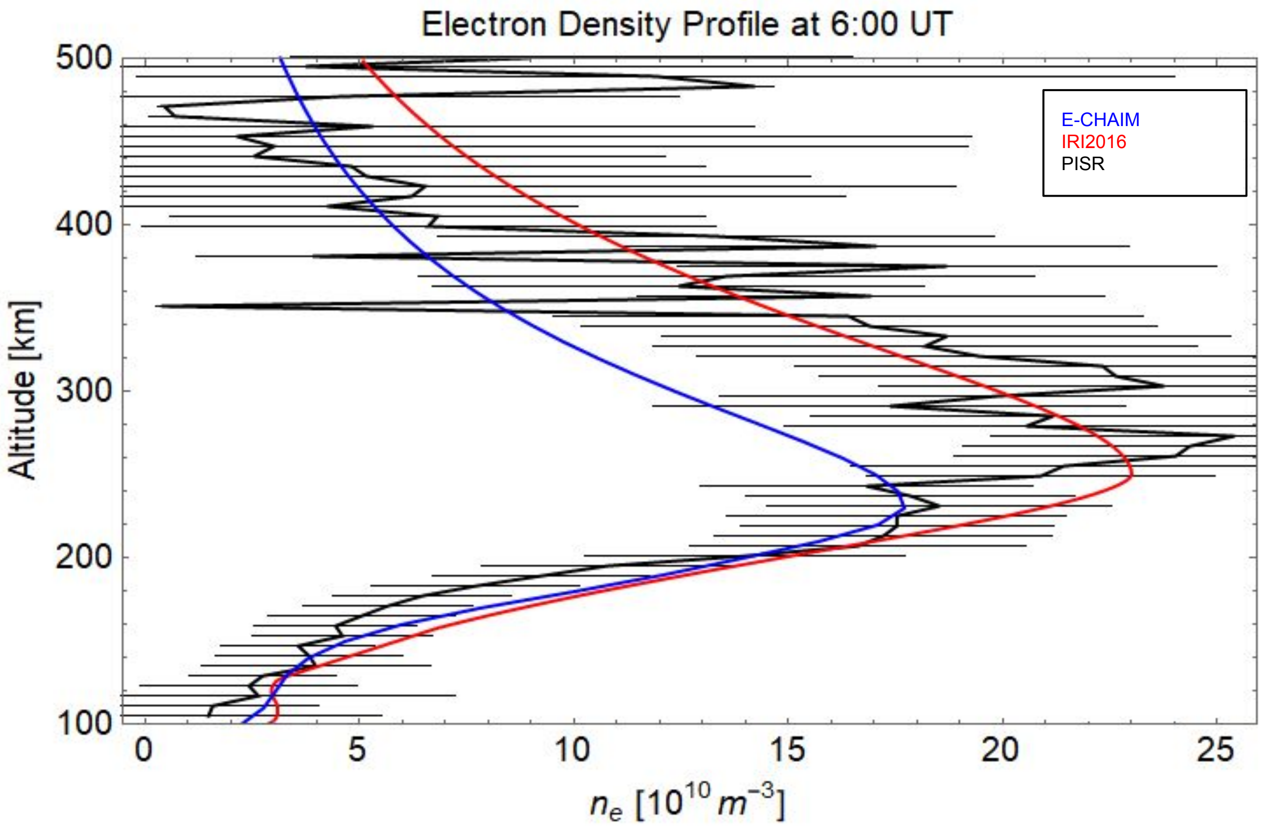
# Model fit to Electron Density vs. Time/SZA at 200 km

- E-CHAIM predicts SZA electron density relationship reasonably
- IRI overestimates electron density at higher SZA



# Model fit to Electron Density vs. Altitude

- IRI has a better F peak prediction than E-CHAIM
- E-CHAIM has no solar activity input into the model



# Summary and Conclusions

- Models may account for solar zenith angle by use of Chapman functions.
- Scale height, H, has a neutral temperature and neutral density profile dependence.
- Electron temperature affects the recombination rate.
- E-CHAIM better predicts SZA dependence in this instance.
- IRI does better in predicting the F peak electron density.

# References


- E-CHAIM Model: https://chain-new.chain-project.net/index.php/chaim/e-chaim/e-chaim-web-application
- Huba, J. D., Joyce, G., and Fedder, J. A. (2000), Sami2 is Another Model of the Ionosphere (SAMI2): A new low-latitude ionosphere model, J. Geophys. Res., 105( A10), 23035– 23053, doi:10.1029/2000JA000035.
- IRI Model Generated by PHaRLAP: https://www.dst.defence.gov.au/opportunity/pharlap-provision-high-frequency-raytracing-laboratory-propagation-studies

# References


- Introduction to the Ionosphere 2020, ISR Summer School, Elizabeth Kendall.
- PFISR data available at: http://isr.sri.com/madrigal/cgi-bin/gSimpleUIAccessData.py